Innovation in IBM Computer Technology

Computers today can process information and solve problems thousands of times faster than could the early electronic systems of the Forties and Fifties—at a small fraction of the cost.

In four decades, the industry has progressed from electromechanical punched card machines and vacuum tube calculators to powerful electronic computers with speeds measured in billionths of a second. This is the result of technical innovation by many people and organizations across the industry—by IBM and other computer producers, universities, customers and individual inventors. IBM has contributed many significant machines, devices, software and manufacturing developments—technology that reflects the company's 10,000 patents and leadership in overall computer research and development. This booklet presents highlights of that technology. The following pages cover the major eras in the evolution of computer circuitry and trace parallel developments in programming, peripheral equipment, manufacturing and research.

The goal in IBM laboratories and plants has not only been to invent but also to apply engineering and manufacturing skills to convert inventiveness into a useful form—new products and systems that are easy to use, are cost-effective, can be produced economically and will perform reliably.

As a result of such innovation by IBM and others in the industry, computers are being put to use at a growing rate across the spectrum of human activity—from science, business and health, to government, education and the arts—in all parts of the world.

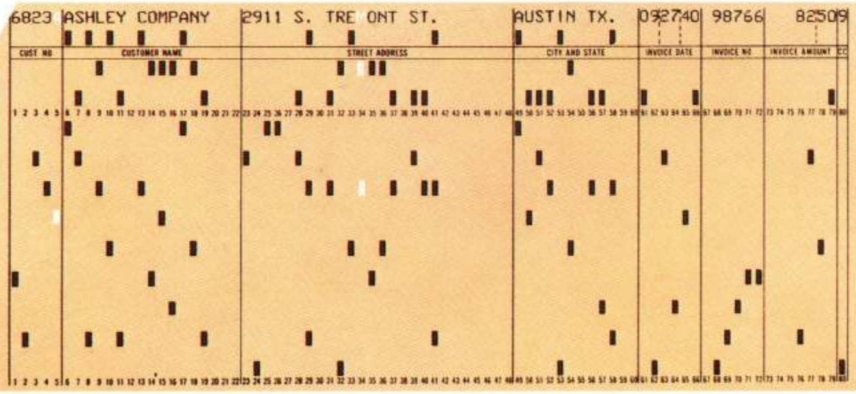
Wires, Wheels and Levers

The Beginning of Modern Information Processing

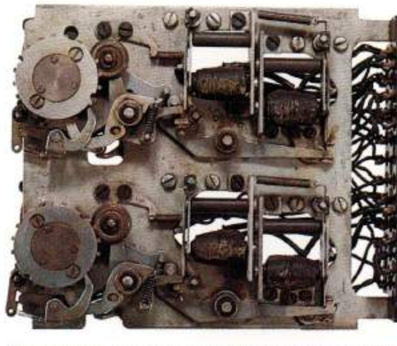
1890-1946

Electromechanical machines to punch, tabulate and sort cards at high speed were the heart of information processing in the U.S. and abroad through World War II.

Originally developed by Herman Hollerith for the 1890 U.S. Census, punched card machines were later put to use by government, railroads and insurance companies. Progressively faster machines came into use throughout business, science and government. However, even the fastest punched card machines were bypassed by technological change, as vacuum tubes began to replace the electromechanical wheels and levers in the late 1940s.

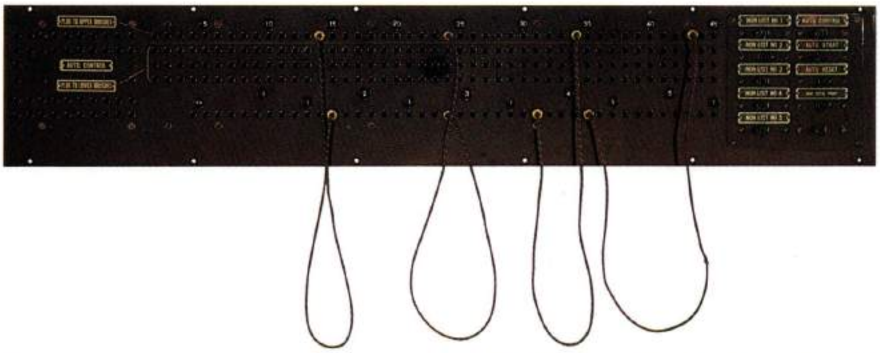


Information is stored in cards by holes punched in columns on the card. Numbers are represented by single holes, letters of the alphabet by two holes. The machine "reads" the holes electrically as the card is moved across sensors.



Electromagnets that controlled counting wheels, together with switching relays, performed the arithmetic function in punched card machines used into the 1960s.

Production of punched card machines grew rapidly in the 1920s and 1930s. This IBM card sorter was used widely until the late 1940s. Many punched card installations continued in operation until replaced by electronic machines in the 1960s.



Wired control panels, or "plugboards," directed the operation of punched card equipment. The operator rearranged the plugs by hand to make the machine do different jobs.

The first operating machine that could execute long computations automatically was the Automatic Sequence Controlled Calculator (Harvard Mark I). A project conceived by Harvard University's Dr. Howard Aiken, the Mark I was built by IBM engineers in Endicott, N.Y., where it is shown before shipment to Harvard in 1944. It was the industry's largest electromechanical calculator.

Punched cards themselves were the basic means of storing information and were often organized in "tub files." This file was typical of the punched card era.

This 3¼-inch-long printing cylinder is from the first machine to manufacture punched cards commercially at high speed—the Carroll Press developed by IBM in 1924. The fast rotary press helped meet the industry's need for billions of punched cards annually.

Vacuum Tubes

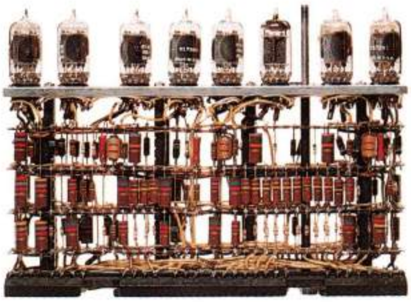
Thousands of Times Faster

1946-1958

The electronic computer was born of the vacuum tube. Developed for the radio industry, the vacuum tube permitted machines to calculate several thousand times faster than did earlier electromechanical relays.

Among the first calculators and computers to use vacuum tubes, built in the years 1946 to 1952, were ENIAC at the University of Pennsylvania, the IBM 603 and 604, the IBM SSEC, EDSAC at Cambridge University, UNIVAC I of Eckert and Mauchly, the Institute for Advanced Study computer and the IBM 701. Some of these incorporated a new "stored program" concept that greatly expanded the machine's ability to do complex work at high speed and helped bring the modern computer into being.

The earliest computers were designed for scientific problems. However, vacuum tube computers moved rapidly into commercial work in the 1950s—in billing, payroll, accounts receivable, inventory control and many other applications.

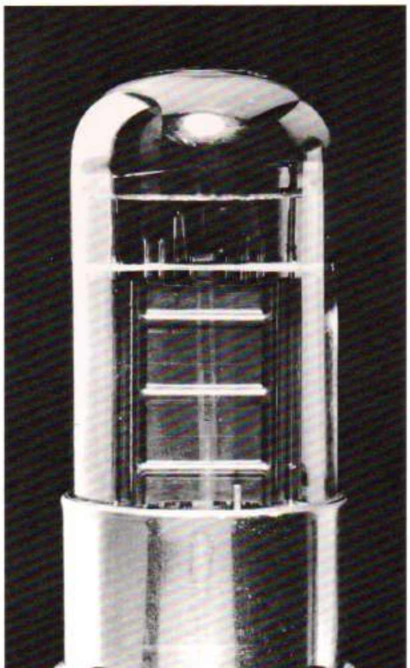


Vacuum tube rack from the IBM 701 computer. First deliveries of the 701 in 1952 signaled IBM's commitment to the new electronic machines—a significant technical and business risk at the time. Principally a scientific computer, the 701 had electrostatic storage tube memory, magnetic tape and drum units, and many electronic circuit refinements. Nineteen 701s were shipped, mostly for government and research work.

The IBM Naval Ordnance Research Calculator (NORC)—the most powerful existing computer when completed in 1954—could perform the calculation below in 31 millionths of a second (including placement of the decimal point).

```
                     2368.912941062
NORC                 867124.0510296
     ------------------------------
                    142134776463 72
                  2132021646955 8
                  473782588212 4
                2368912941062
              11844564705310
            9475651764248
          4737825882124
        2368912941062
      16582390587434
     14213477646372
    18951303528496
   --------------------------------
    2054141385.9901255052174352
```

The widely used programming language FORTRAN was developed originally by IBM and made available to users in 1957. FORTRAN enables engineers and scientists using a computer to state a problem in familiar symbols, close to the language of mathematics.



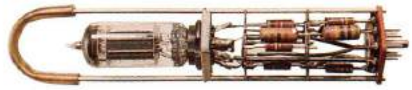
The vacuum tube in early computers was used basically to switch electrical signals to perform operations such as adding, multiplying, storing and comparing.

Typical mathematical formula:

D=B²-4AC

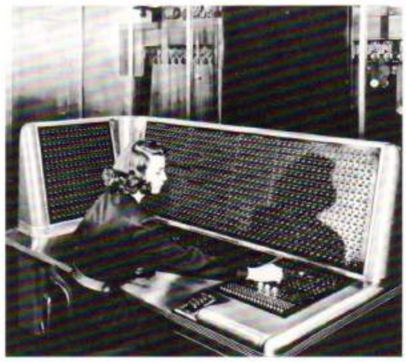
Equivalent FORTRAN statement:

```
D=B**2-4*A*C
```



The computer industry's first "replaceable unit" was this assemblage of electronic parts in the IBM 604 calculator in 1948. Service engineers could simply plug in a replacement.

The largest of all vacuum tube machines was SAGE, a computer used as part of the U.S. air defense system. Twenty-seven were built by IBM during the 1950s in a program directed by the Massachussetts Institute of Technology's Lincoln Laboratory. SAGE was the first large computer network to provide man-machine interaction in "real time"—as events were occurring.



The first operating computer to combine electronic computation with stored instructions was the IBM Selective Sequence Electronic Calculator (SSEC), completed in 1948. It had more than 12,000 vacuum tubes and 21,000 electromechanical relays.

Magnetic Storage

Better Ways to File and Retrieve Information

1952-1962

In the 1950s, new ways to store more information were in demand. Early electrostatic storage, using cathode ray tubes, was fast, but could be expensive and troublesome. Punched cards were low-cost, but slow. Computer tape could be a problem because of delays when data was recorded at scattered points on a reel.

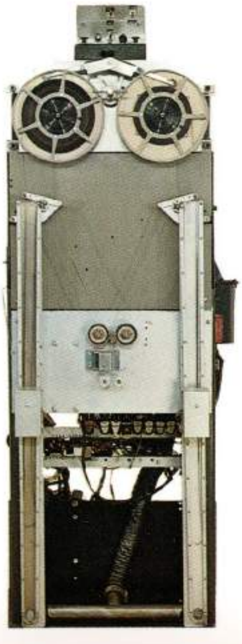
The answer for high-speed main memory within the computer turned out to be the tiny magnetic core, originated by several inventors and organizations. The answer for large-volume storage was the IBM-invented magnetic disk, which enabled users to retrieve any piece of information directly, in less than a second. This was significant for a wide range of users who needed fast access to files.

In this same period, better ways were also found to program the computer and to improve its communications ability.

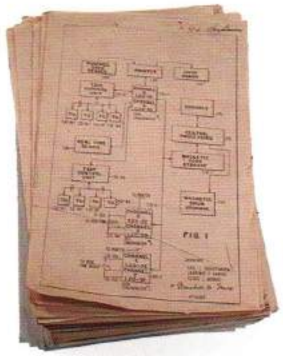
Data processing took a new direction in 1957 with initial delivery of the IBM 305 RAMAC (above), the first computer disk storage system. Such machines became the industry's basic storage medium for on-line transaction processing. In less than a second, the RAMAC's "random access" arm could retrieve data stored on any of 50 spinning disks.

Left: In 1962, IBM introduced the first storage units with removable disks. Each "disk pack" on the IBM 1311 could hold more than 2 million characters of information. Users could easily switch files for different applications.

Right: This 1950 laboratory model proved out IBM's "vacuum column" invention for controlling magnetic tape. The glass vacuum chamber provided leeway for the tape and prevented it from breaking when abruptly started or stopped. This technique was to be adopted throughout the industry.

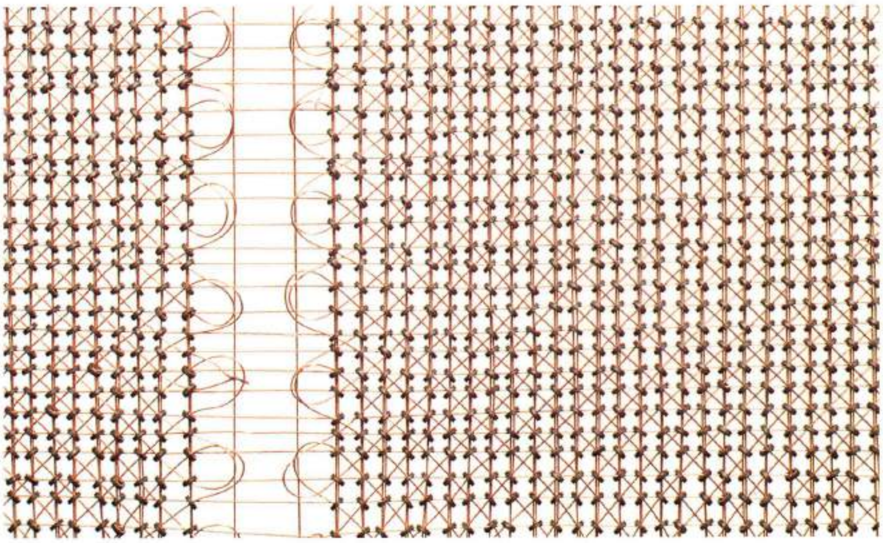


This 16-inch-long drum spun at 12,500 revolutions per minute to provide the IBM 650 computer of the mid-1950s with 10,000 characters of main memory. Data was magnetically encoded on 40 tracks around the drum.

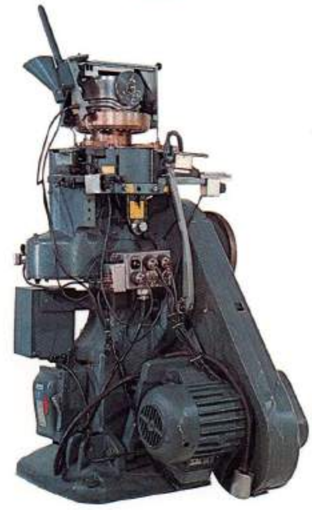


Copy of the 1,115-page patent application covering IBM's 1954 invention of the computer "channel." Operating under its own program, the channel synchronized the flow of data into and out of the computer while computation was in process, relieving the central processor of that task. The channel was later widely adopted in the industry.

Below: Magnetic cores originated with two inventors, A. Wang and F.W. Viehe, who independently began experimenting with cores for computer memory in the 1940s. Later development work was done by others, including the Massachussetts Institute of Technology, the Radio Corporation of America and IBM. In the 1950s and 1960s, cores were progressively miniaturized to produce higher-speed memories.

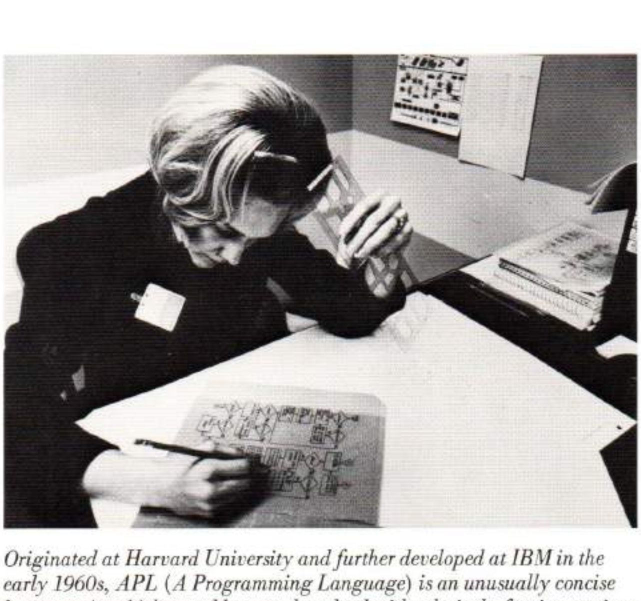


Magnetic cores were the basic technology for computer main memory from the 1950s into the early 1970s. The tiny iron oxide cores could be magnetized clockwise or counterclockwise to represent bits of information. Data could be retrieved in millionths of a second.



IBM adapted pill-making machinery to produce tens of billions of cores in the 1950s and 1960s. Shown above is a Colton Manufacturing Co. machine redesigned by IBM to compress ferrite powder into 32,000 cores an hour. Among many other automated techniques, IBM designed wire feeders to string thousands of cores in one operation.

The IBM 701 system in 1952 was one of the first computers to use magnetic tape for reading, writing and storing information. Recording at 100 characters per inch, this 8-inch-diameter reel was equivalent to 12,500 punched cards. The 701's tape units contained a new vacuum column and magnetic clutch tape drive system and were among the first to use plastic rather than metal tape.



Originated at Harvard University and further developed at IBM in the early 1960s, APL (A Programming Language) is an unusually concise language in which a problem can be solved with relatively few instructions. APL today is popular for engineering studies and systems design and is used by many business professionals.

Transistors

Smaller, Faster, More Reliable

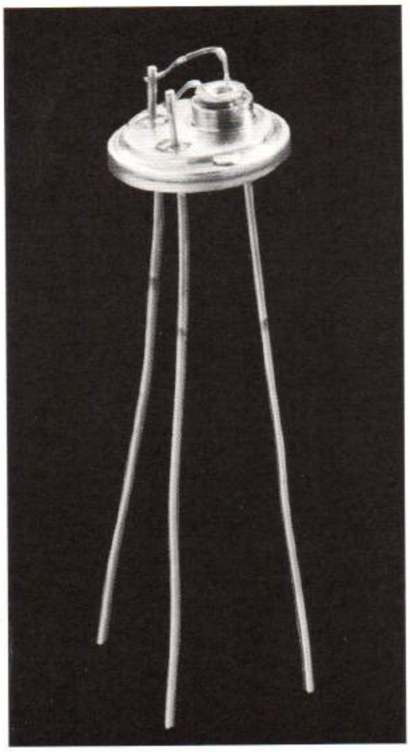
1957-1964

The invention of the transistor at Bell Laboratories in 1947 foreshadowed the time, a decade later, when the device would give birth to a new "generation" of computer technology. As a replacement for the vacuum tube, the tiny transistor shortened the time needed for electrical pulses to complete a circuit. It generated less heat, was much more reliable and lowered production costs.

Ways were found to incorporate the new transistor technology into computers and to automate the manufacture and testing of transistors by the millions. At the same time, computer companies intensified their development of new systems—both computing equipment and programming support—to meet the needs of many different users, large or small, in business, science and government.

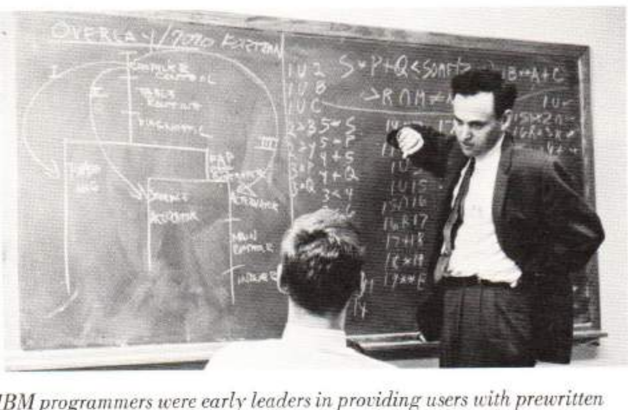
Right: Only 1/200th the size of an early vacuum tube and using less than 1/100th the power, the transistor came into general use in computer systems about 1960. The transistor's basic function in a computer is that of an electrical switch to perform logical operations.

In 1959, the transistorized IBM 1401 brought computer use within the reach of smaller organizations for the first time. Much more powerful than vacuum tube machines of comparable size, the moderately priced 1401 was popular with banks, retail chains, manufacturers and other organizations. In six years, more than 10,000 were delivered.

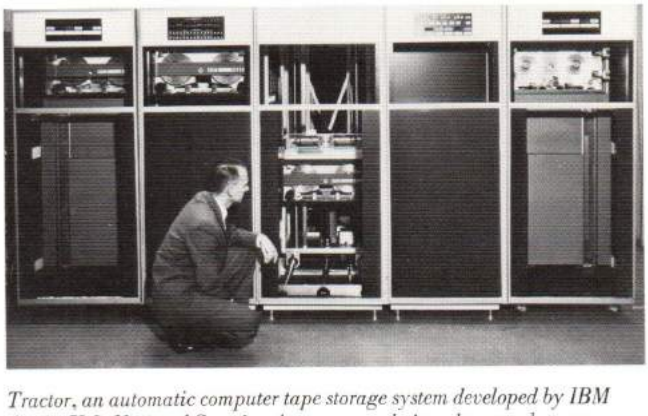


Typical of what transistors meant to computing was the higher speed of the IBM 7080. The same programs written for payroll, billing and inventory on the older vacuum tube IBM 705 ran six to ten times faster on the transistorized 7080.

The "chain" printer for computers was introduced with the IBM 1401 computer in 1959. Improving both speed and reliability, the new machine printed 600 lines a minute from a chain-loop of characters moving at 90 inches a second. The technology was later used widely in the industry.



IBM programmers were early leaders in providing users with prewritten computer programs. Such systems software included instructions for sorting and merging data, controlling input and output, and generating reports. Users of the IBM 7090 computer in 1961, for example, could take advantage of more than 1 million such prewritten machine instructions.



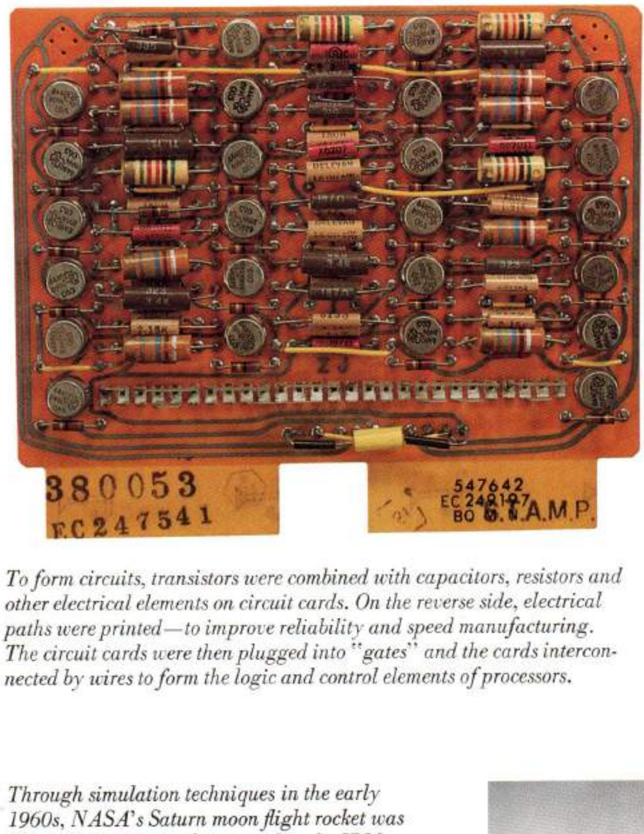
Tractor, an automatic computer tape storage system developed by IBM for the U.S. National Security Agency, was designed to attach to an enhanced IBM Stretch computer. Delivered in 1962, Tractor could store the equivalent of 88 billion characters in 160 cartridges. Its read/write speed of 1.1 million characters per second was the fastest achieved for magnetic tape during the 1960s.

The first fully automatic production line for transistors was designed by IBM engineers in Poughkeepsie, N.Y., and placed in operation in 1960. Up to 1,800 individual transistors were produced and tested per hour.

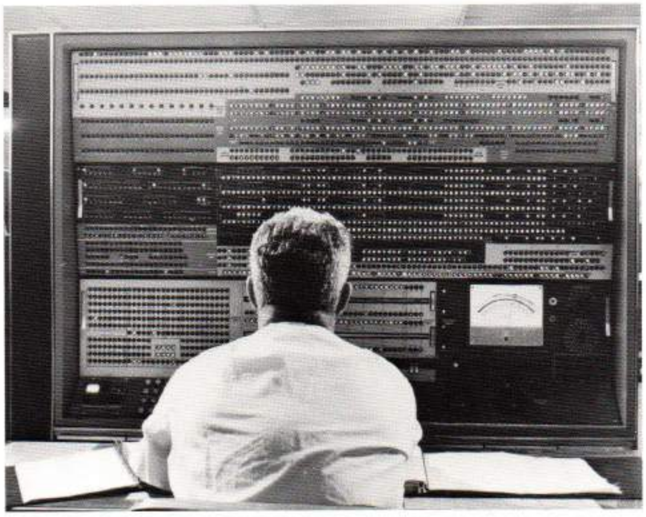
The Target

An IBM engineer's view of the company's computer development of the late 1950s:

"The key wasn't only the transistor card, it was the whole circuit packaging system—the back panel, the gate, the industrial design, the memories, the power supplies. Everything had to be standardized to assure high, *predictable* reliability, at reasonable cost, machine after machine after machine."



To form circuits, transistors were combined with capacitors, resistors and other electrical elements on circuit cards. On the reverse side, electrical paths were printed—to improve reliability and speed manufacturing. The circuit cards were then plugged into "gates" and the cards interconnected by wires to form the logic and control elements of processors.



Maintenance console of IBM's Stretch, the industry's most powerful computer when first delivered in 1961. Stretch had 150,000 transistors and could perform 100 billion computations a day. Stretch pioneered in various advanced systems concepts, known in industry terminology as look-ahead, overlapping/pipelining of instructions, error-checking and correction, control-program operating systems and the 8-bit byte.

Through simulation techniques in the early 1960s, NASA's Saturn moon flight rocket was "flown" thousands of times within the IBM 7090 computer before real flight. The fully transistorized 7090 could perform 229,000 calculations a second.

The SABRE reservation system for airline passengers was the first large, high-speed commercial computer/communications network that operated in "real time"—handling transactions at the time they occurred. It was developed by IBM for American Airlines over six years of joint research and became operational in 1962.

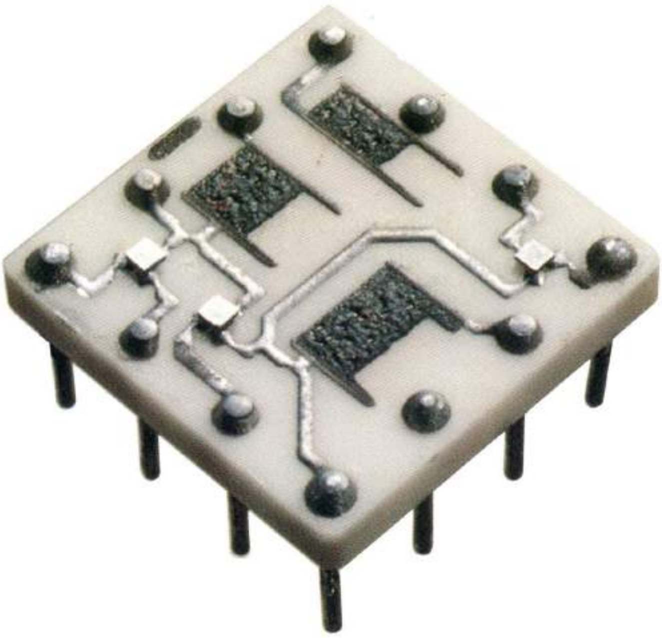
Solid Logic Technology

For System/360 — First Big "Family" of Computers

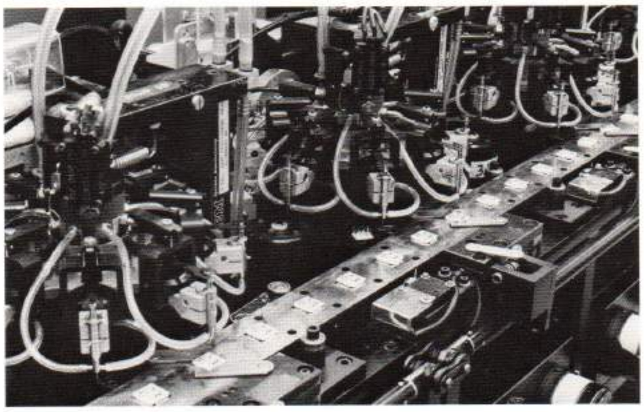
1964-1971

In 1964, IBM System/360 was introduced. Incorporating new Solid Logic Technology, System/360 replaced IBM's existing computer product lines. It was the first "family" of computers—ranging from small to large—that were both upward and downward compatible, using the same programming instructions. In most cases, the input/output, storage and other equipment could be used interchangeably with any of the central processors.

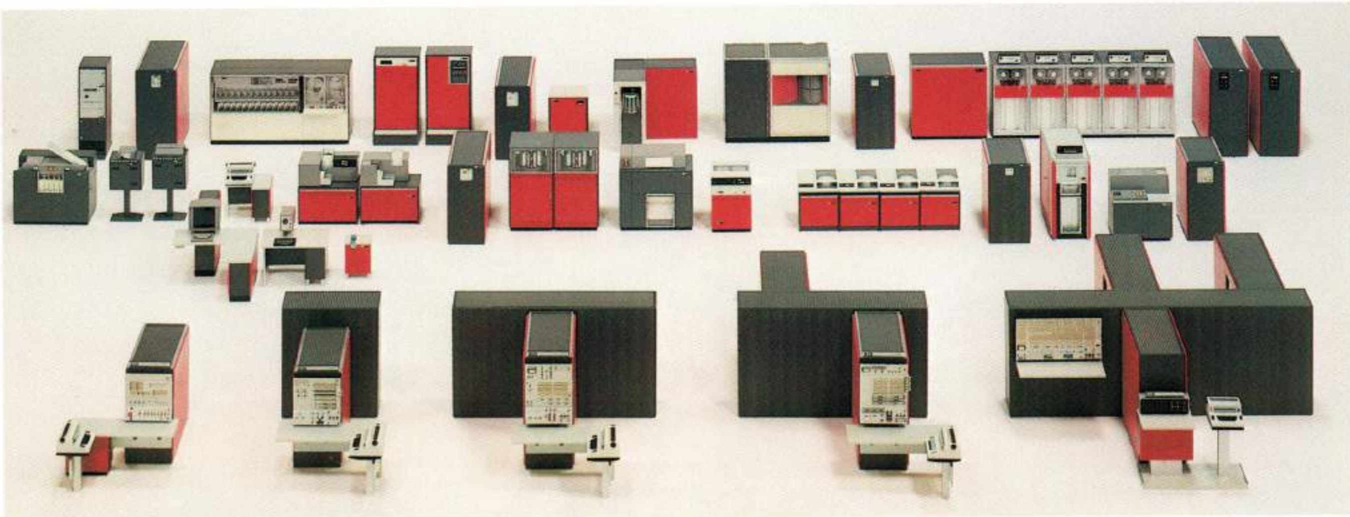
During the 1960s, computer storage grew in capacity and speed. Programming took on greater importance. Major focus was on software systems designed to make the most efficient and productive use of the computer.



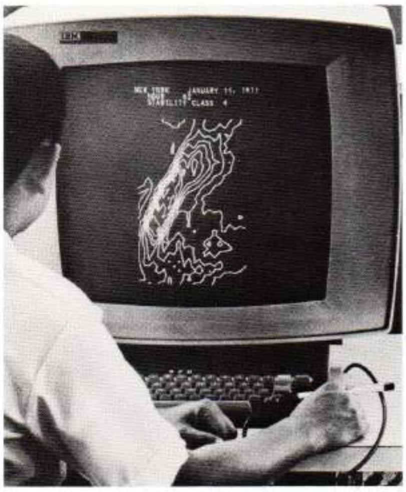
The Solid Logic Technology (SLT), introduced by IBM in System/360, was the industry's first high-volume, automatic, microminiature production of semiconductor circuits. Mounted on ½-inch-square ceramic modules (left), the SLT circuits were denser, faster and required less power than the previous generation of transistor technology.



SLT was fast and reliable, and because of IBM's automation of basic tools it could be mass-produced on the scale demanded by System/360. Statistically, the average time before failure of an SLT module was more than 33 million hours.



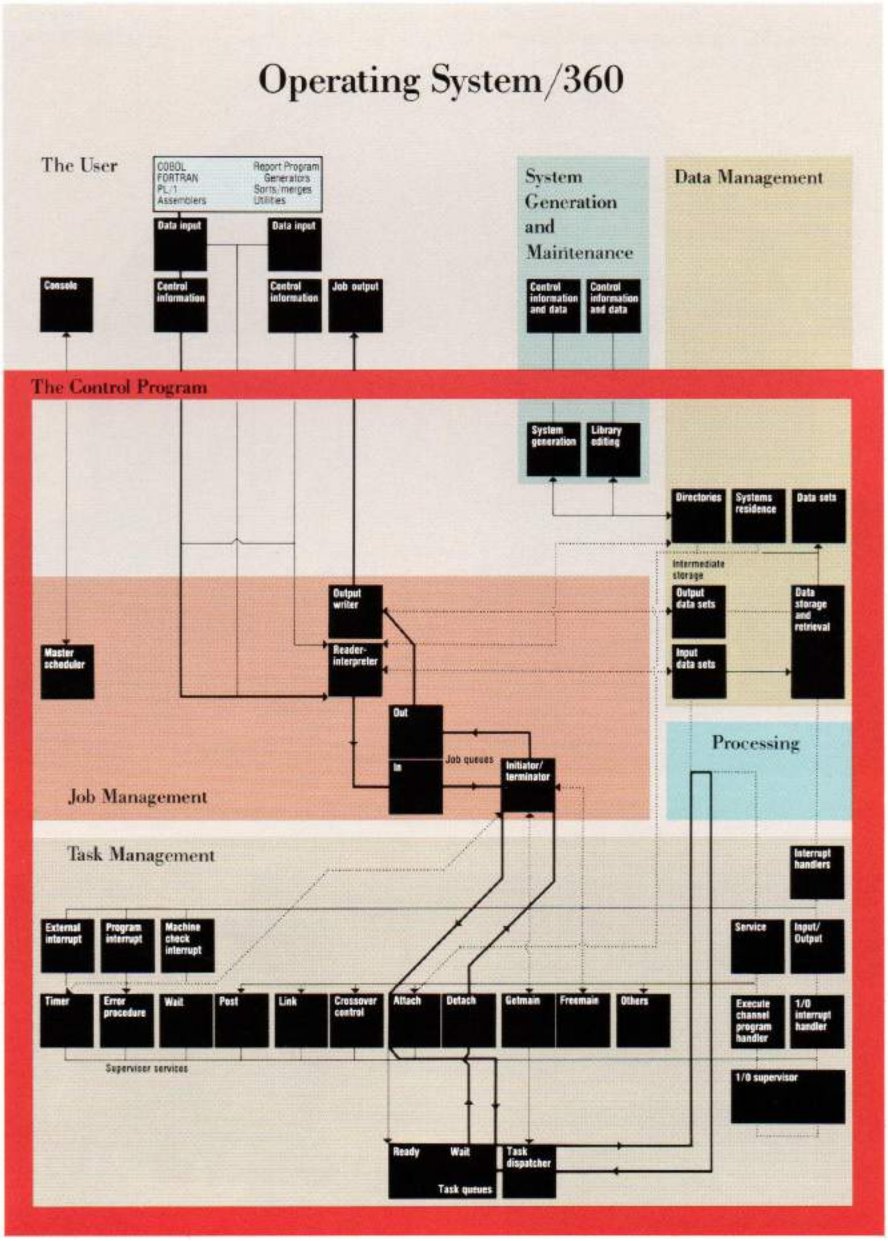
In the foreground of this scale model are the central processors of the first five computers announced as part of the IBM System/360 in 1964. To the rear are many of the input/output and storage attachments available at announcement time. Those units could be connected interchangeably with the different processors. Instructions written for one of the System/360 computers would work with any of the others.



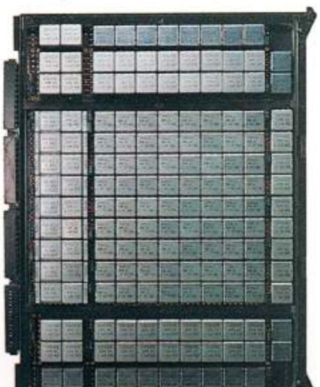
Left: Introduced with System/360 in 1964 was a machine displaying information in the form of charts, graphs and dynamic computer drawings. Primarily a design tool, the IBM 2250 enabled designers to perfect their work on the screen through use of the keyboard and light pen. Among many applications, the 2250 displayed maps of air pollution over big cities, as part of studies of smog control.

Right: Hundreds of IBM programmers wrote more than 3 million instructions to produce Operating System/360.

Determining where hundreds of thousands of electrical connections must be made was one way existing IBM computers were used to automate the design and manufacture of System/360. Dozens of other new manufacturing techniques and machines were also developed.



Circuit card from the industry's first sizable, high-speed "cache," or buffer, memory, introduced in the IBM System/360 Model 85 computer in 1968. The semiconductor cache memory could make priority information available for processing in 80 billionths of a second—about 12 times faster than the main magnetic core memory.



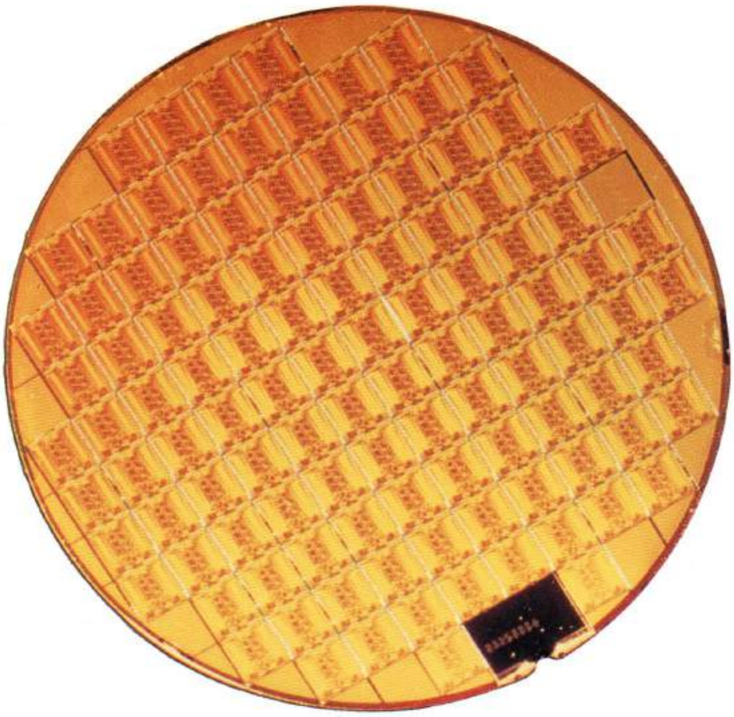
Operating System/360 was a set of programs that permitted the computer to process a continuous flow of different jobs without interruption. It automatically controlled the computing units, language translators, storage units, job control programs and data flow to provide greater "throughput"—or productive work—for users of System/360.

Integrated Circuits

More Problem-Solving for Less

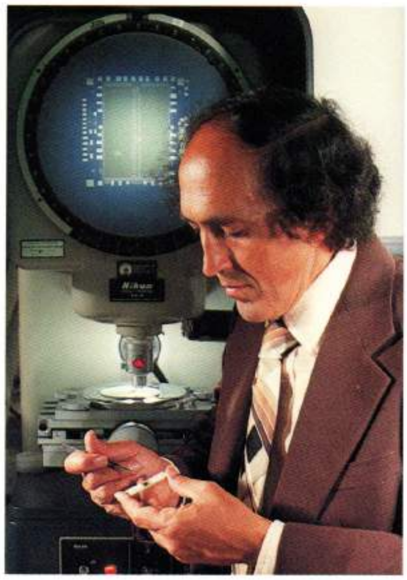
1970s

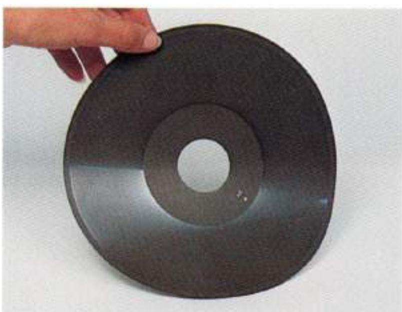
Full-scale use of monolithic, integrated circuit technology was introduced in the early 1970s. That technology places many circuits on single, tiny silicon chips. The industry's first computer with an entire main memory of monolithic technology was the IBM System/370 Model 145, delivered in 1971. Very dense, large-scale integration of both memory and logic technology brought major gains in speed, capacity and reliability. Also introduced in the 1970s were storage concepts and devices that greatly increased the amount of data that could be stored, as well as the ease of handling it. Users with complex applications could now work with millions or billions of characters of information. Programming was tailored ever closer to the needs of the user in health care, manufacturing, government, education and many other areas.



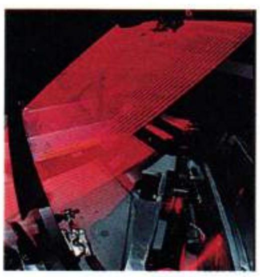
This 3¼-inch production wafer contains 109 silicon memory chips, each able to store 64,000 bits of information. In 1978, IBM was the first to mass-produce 64,000-bit chips for use in production line computers.

IBM's 1967 invention of the dynamic memory cell—using only one transistor per bit of information—permitted major increases in computer memory density. This technology was later adopted throughout the industry.

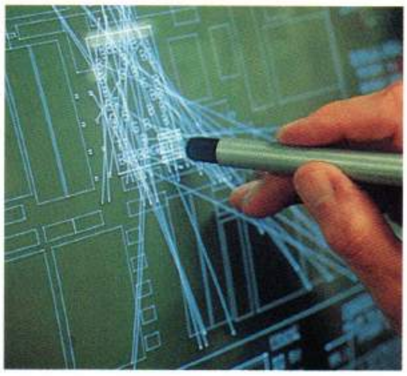




The industry's first flexible magnetic disk, or diskette, was introduced by IBM in 1971. Such "floppy disks" greatly increased the convenience of data handling. They are now widely used as a basic storage medium for small systems.

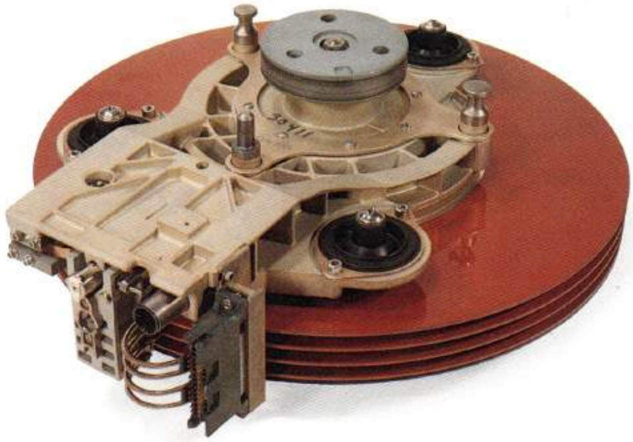


The IBM 3800 laser-electrophotographic printer has a speed of 20,000 lines a minute in preparing bank statements, premium notices and other high-volume documents. Laser beam paths are altered millions of times a second and are reflected from an 18-sided mirror that spins at 12,000 revolutions per minute.



Through computer simulation of complex functions, an IBM engineering design system using graphic displays has speeded the circuit development of more than 100 IBM computer products.

Built into IBM System/370 Model 145, delivered in 1971, was the first computer main memory made entirely of monolithic, integrated circuit technology. The Model 145 initially offered up to 131 of the circuit cards shown in the open gate. That many cards held more than 262,000 characters of information, any of which could be retrieved in 200 billionths of a second.



In 1973, the IBM 3340 disk unit introduced to the industry an advanced disk technology known as "Winchester," after IBM's internal project name. The 3340 featured (1) a smaller, lighter read/write head and (2) a ski-like head design that enabled the head to ride closer to the disk surface—on an air film 18 millionths of an inch thick. The 3340 doubled the information density of IBM disks—to nearly 1.7 million bits per square inch.

Above: The merchandise scanner in IBM's supermarket checkout station incorporates a spinning disk of 21 holographic films that function as glass prisms and lenses. A laser beam passing through the disk creates a complex light pattern that strikes the Universal Product Code stripes on merchandise held over the scanner. Light reflected from the stripes is converted by the scanner into electrical signals for computer processing.

The IBM System/370 of the early 1970s could read or write on magnetic tape at rates as fast as 1,250,000 characters a second. The contents of a 1,500-page dictionary could be read from the tape reel in about 13 seconds. The rate resulted from high reel speed and high data density on the tape.

Below: A high level of security in protecting computer data transmitted over communication lines is provided by an IBM-invented cryptographic algorithm for making a stream of characters unintelligible. Incorporated into the IBM 3845 encryption unit, the algorithm can accept more than 70 quadrillion possible keys, making unauthorized discovery extremely difficult. It has been adopted as a national standard by the U.S. Government and the American National Standards Institute.

By the early 1970s, more than 6 million computer instructions had been written by IBM programmers to help users of larger IBM computers operate their systems more economically and productively. Users of early computers in the 1950s had to write most such instructions themselves.

The "honeycomb" cell structure of the IBM 3850 mass storage system, introduced in 1976, stores small cartridges containing reels of magnetic tape. Each reel can store 50 million characters of information. Up to 472 billion characters can be economically filed in one 3850 system for on-line computer use.

Very High Densities

More Speed, Function, Capacity, Reliability

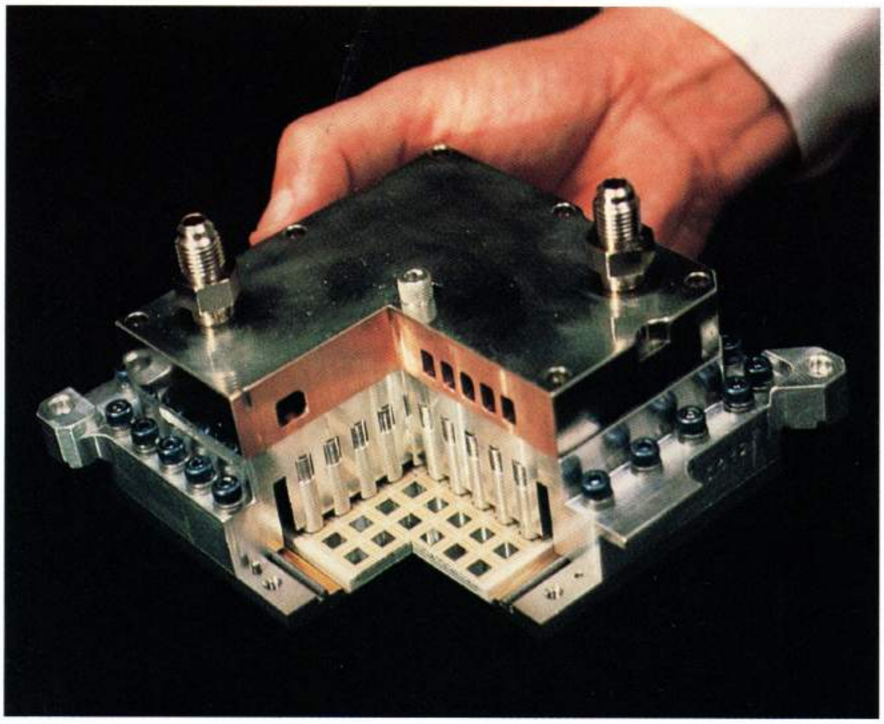
1980s

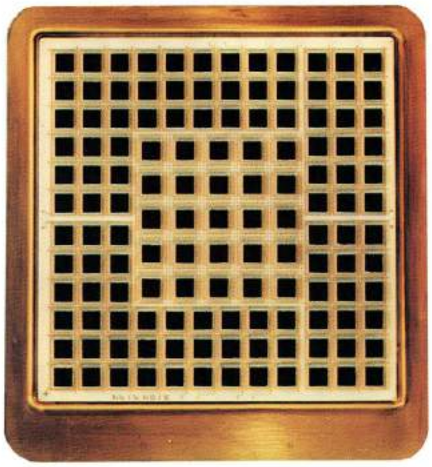
The industry's rapid rate of technological change is continuing in the 1980s, raising productivity for the computer user.

Silicon memory and logic circuits are being further miniaturized for better cost-performance over the full range of computers—from large systems to the smallest microprocessors in remote workstations.

Greater recording density in magnetic disks and tapes is increasing storage capacity and read/write speed. New communication, display and printing technologies are expanding the computer's usefulness.

Significant programming advances are making the computer still easier to use and more adaptable to specific needs.

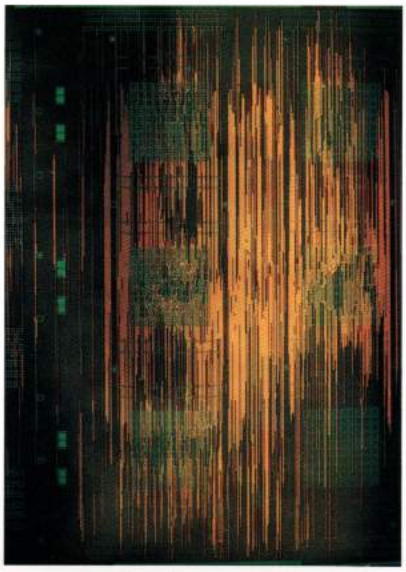


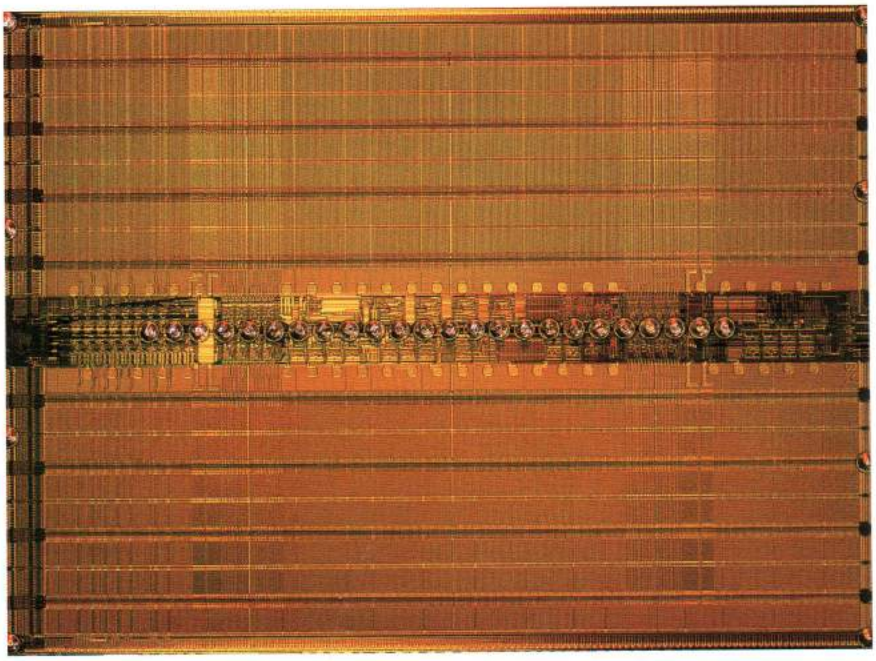


Today, the information processing power of electronic computers of the 1960s can be held in one hand. The logic module used in the large IBM 3081 system, introduced in 1980 (cutaway at left), is part of the industry's densest circuit packaging technology. Up to 133 electronic chips mounted in each module (above) contain a total of 45,000 logic circuits, as well as other circuitry.

Left: Magnified several hundred times, this copper coil is part of the "thin film" recording head used in several IBM disk files. It was introduced in 1980. The IBM 3380 file uses the technology to read and write data at 3 million characters a second, the first commercial unit to achieve such a rate. (Light refraction from minutely separated film layers produces the iridescent color pattern.)

Right: This 24 x 28-inch copper plane is part of the densest computer circuit packaging yet reported. Used in large IBM computers, the plane is one of 20 layers in a 1/5-inch-thick printed circuit board that contains nearly a mile of wire interconnections.





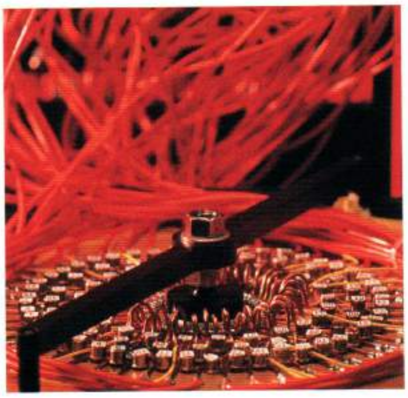
This IBM computer memory chip, 3/8-inch long, stores more than 1 million bits of information. IBM was the first to develop and mass-produce chips of this density. At the start of 1987, the only such chips operating in the industry were in the IBM 3090, System/38 and System/36 computers and in the IBM 3880 disk "cache" control unit.

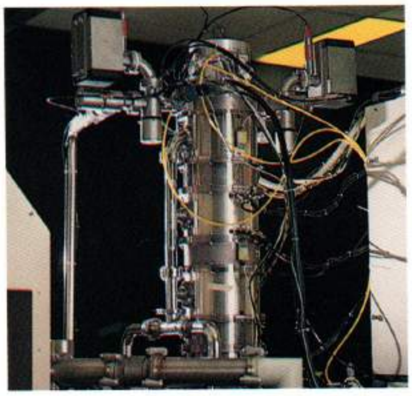
Highly magnified area of a magnetic disk surface in the IBM 3380 shows elongated information bits recorded along six of the disk's 1,774 concentric tracks. One square inch of disk surface contains about 22 million bits.

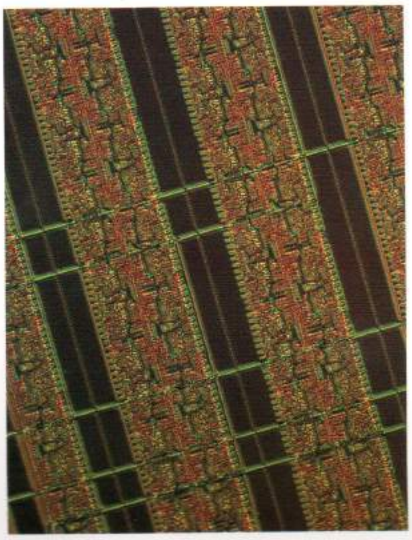
An IBM-designed, electron-beam machine can interconnect circuits on as many as 2,000 high-density computer chips per hour. This is the fastest plant production rate for the lithographic electron-beam process. A beam narrower than 1/10,000 of an inch traces intricate circuit patterns under computer control.

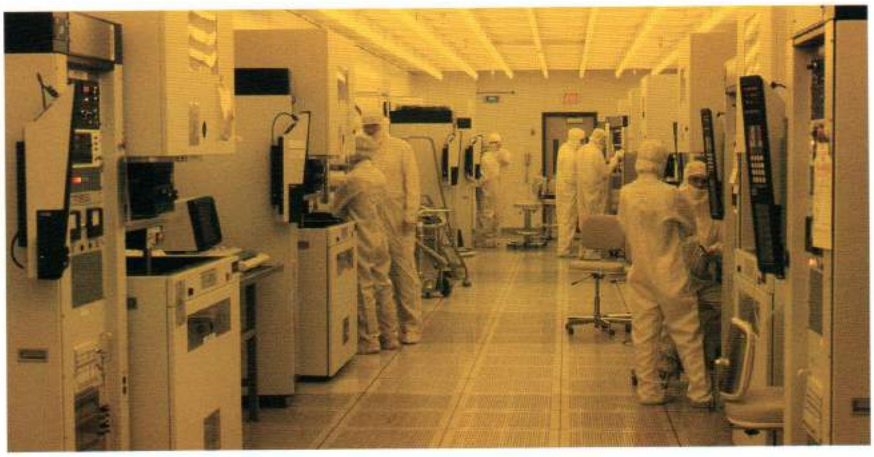
Right: By 1981, more than 50 computer-controlled systems designed by IBM were quality-testing thousands of different circuit parts on IBM production lines. In less than a minute, this device could test a silicon wafer that had more than 100 complex logic or memory chips containing thousands of transistors.

Below: IBM has pioneered the computer industry's development of "masterslice" technology for the economical design and production of very dense circuitry. Shown is a segment of a chip fabricated for IBM processors. A predefined circuit pattern is repeated on silicon wafers, producing a "masterslice" containing many arrays of identical circuit-element cells. Designers can then economically add new circuitry to "customize" hundreds of chip variations.









New IBM plants in East Fishkill, N.Y., and Essonnes, France, incorporate the industry's most advanced process technology for producing very dense logic chips. To control contamination by dust or other foreign materials, ultra-clean air flows continuously from ceilings to floors. To prevent vibration harmful to circuit fabrication, the five-acre middle floor containing manufacturing processes is supported independently of the top and bottom floors, which house airflow equipment and materials distribution.

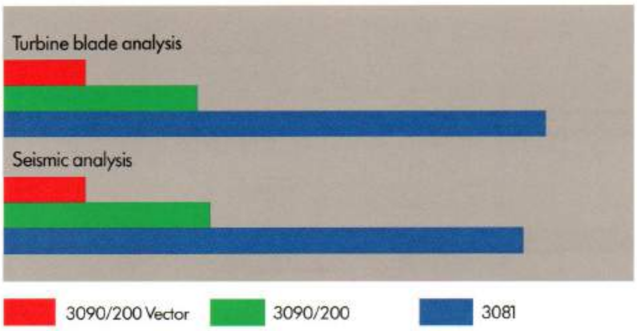
Advanced Systems

Processing Power and Software for Big Tasks

1980s

Advancing technology is making it easier to apply computers to very large, multi-user applications in the business world, science and engineering. Ever more-powerful computing systems and the control software for complex tasks are emerging from the laboratory. In addition, easy-to-use smaller computers are acquiring the capabilities of yesterday's largest systems.

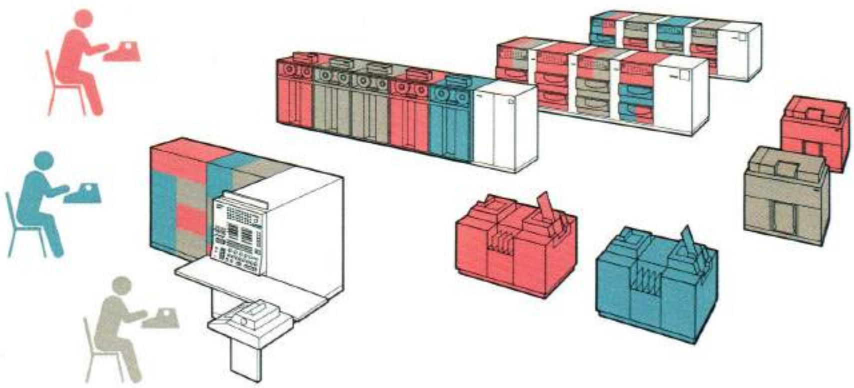
The industry's most advanced general-purpose computing system available at the start of 1987 was the IBM 3090 Model 400. It links four powerful computers in parallel processing. Vector processors significantly enhance its scientific computing speed. The system's 1-million-bit memory chips are the industry's highest-capacity. The logic circuits have the densest packaging yet developed. The leading-edge technology in the system's "thin film" head disk files and cartridge tape drives has been adopted by others. The system's operating system control programs are the most advanced yet developed. Engineering design and manufacturing techniques make the system highly reliable.



This chart shows the shorter time needed to perform typical engineering and scientific applications on an IBM 3090 Model 200 computer with one attached "vector" processor (red bars) compared with times for the same system without a vector and for a comparable previous IBM 3081 computer. In vector processing, the computer performs arithmetic operations on long columns of numbers, called vectors, by executing a single instruction. The IBM vector processor shipped for the IBM 3090 computer in 1986 was the industry's first offered with the full utility of Multiple Virtual Storage and Virtual Machine control software.

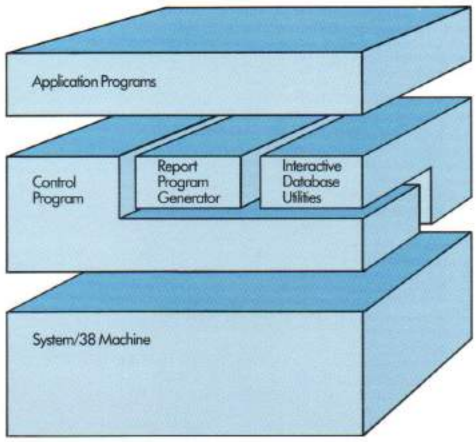
IBM programmers have written more than 1 million computer instructions for U.S. Navy submarine sonar systems, in addition to developing and building the systems. IBM has also integrated the command and control system in the Trident-class Navy submarines, involving 170 principal pieces of equipment.

Virtual Machine architecture (VM) is a programming and systems design approach that enables multiple users at terminals to share a computer in a highly flexible manner —virtually as though each were using a separate version of the computer. Developed by IBM and others in the 1960s, Virtual Machine was made available on System/370 in 1972 and is now used in advanced forms on a wide range of IBM systems. A control program automatically shares the computer's processing time in split seconds among all users. The program also allocates the user's work among existing devices, reducing the need for equipment.



The relational data base concept of filing, modifying and retrieving computer information was originated by IBM and has been implemented and tested by IBM researchers since 1970. Information in the computer is arranged in easy-to-interpret tables. The method minimizes the need for computer experience, since users can merely specify what they wish to do, without having to instruct the computer on how to do it. The method has been implemented in the IBM Database 2 and SQL/DS software products.

The industry's highest-capacity computer memory chip fabricated on a production line in 1981 was this 3/8-inch IBM chip able to store more than 288,000 bits of information.



Equipment and programming functions normally associated with large systems are combined in the mid-range IBM System/38 computer. A control program transfers much of the burden of managing internal operation from the user to the computer. System/38 was first delivered in 1980. The system is unusually easy to use and program, especially for interactive data base applications. It incorporates IBM's 1-million-bit chip and is designed to take advantage of very large main memory. Up to 256 workstations can be locally attached.

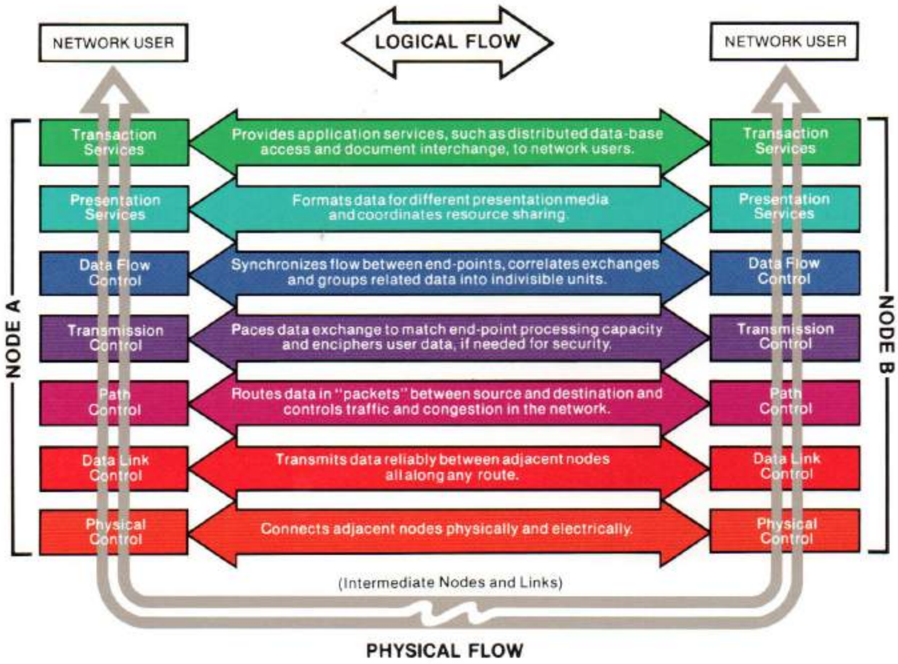
The industry's most advanced magnetic tape system, the IBM 3480, replaces the familiar reels of tape with small, easily handled cartridges. The 3480 units (foreground in picture) require only 60% of the floor space and power of the previous IBM 3420 drives and have significantly greater reliability. The 3480 was the industry's first tape system to use "thin film" recording head technology, doubling the read/write speed to 3 million characters a second.

Telecommunications

Timely Information for the User

1980s

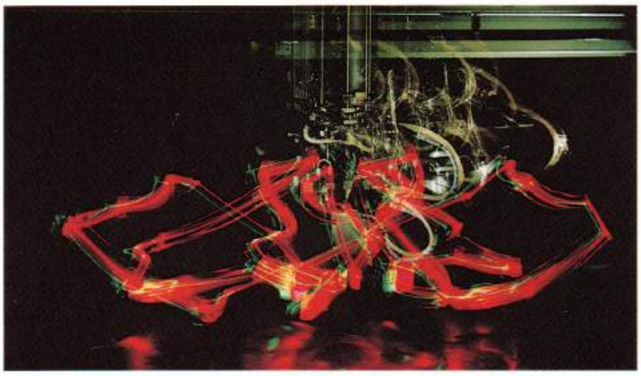
As the computer industry places more and more computing power and storage in workstations, it is significantly altering the structure of information systems. Many more users now seek access to data bases over communication lines and to exchange information with one another. The need grows for connectivity among many different products. Interest in computer graphics is expanding, requiring much higher transmission rates. Today's computer networks are only the beginning.



This is a representation of the overall design of IBM Systems Network Architecture (SNA)—an organized structure for operating many kinds of computer/communications networks. Since the mid-1970s, IBM programmers have collectively spent a total of several thousand years in developing software to free computer users from the technical complexities of communication through local, national and international computer networks.

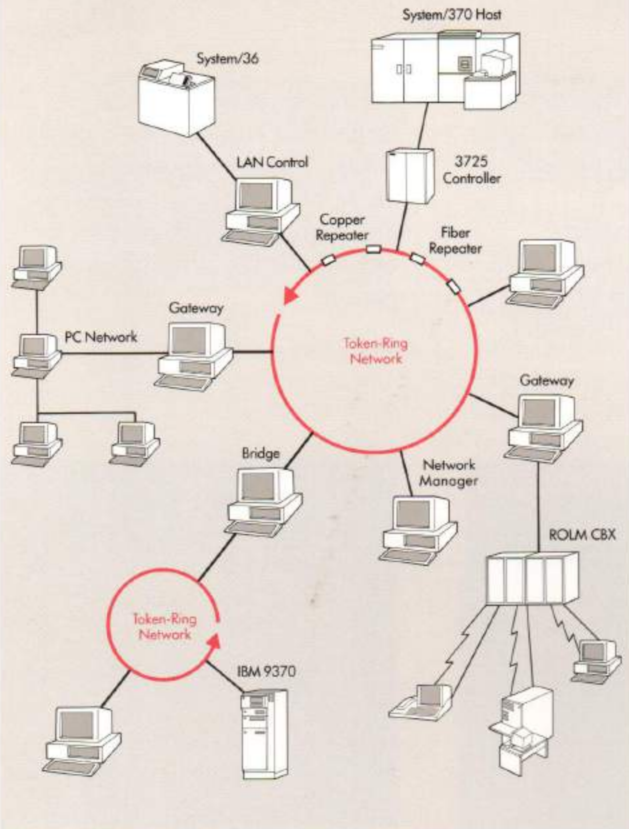
The industry's most advanced software for managing large computer communication networks, IBM NetView, consists of nearly a half million instructions for monitoring and supervising the telecommunications functions of large network control units, workstations, terminals and the communication functions of large computers. NetView is designed to provide a single focal point for management services, a growing priority as networks become larger and increasingly complex. A user having communications difficulty with an application can view the network through NetView and pinpoint the problem area.

A gas-panel display screen technology introduced by IBM in 1983 produces flicker-free images from a grid of wires with ¾-million intersections. Ionized neon-argon gas glows at selected intersection points (photo at right) to create high-resolution characters and illustrations. Techniques developed by IBM for very precise fabrication of the wire grid produce the high image quality.

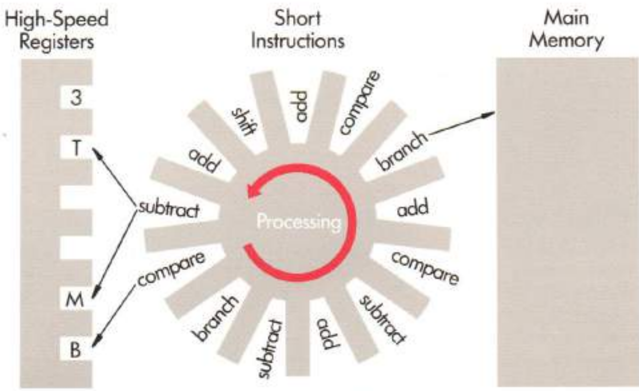


High-precision, programmable IBM robotic systems use the most advanced commercially available robotic control language. The IBM-developed AML (A Manufacturing Language) has language features especially suitable for creation of application programs for many automated plant floor tasks.

Local Area Networks

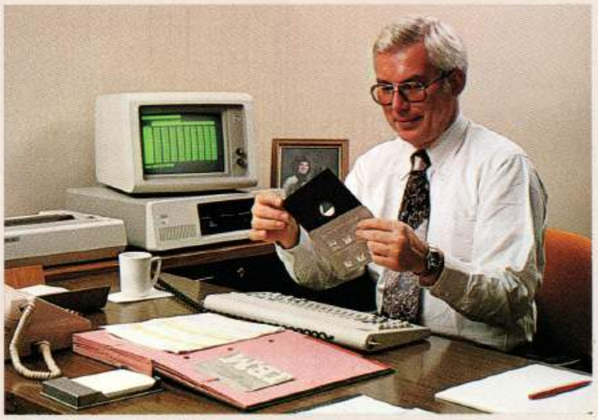


The IBM Token-Ring local area network, introduced in 1985, permits personal computer users to exchange information and share printers and files within a building or building complex. The data transmission rate at the start of 1987 was 4 million bits a second. Senders capture "tokens" passing on the ring and add messages to send to recipients. Personal computer users can have quick access to larger computers and other local networks. Through computerized telephone branch exchanges (CBX), they also can communicate with both local and remote users, as well as data bases and applications outside the local area network. IBM programs permit personal computers to perform such networking functions as LAN control, gateway, bridge and network management.

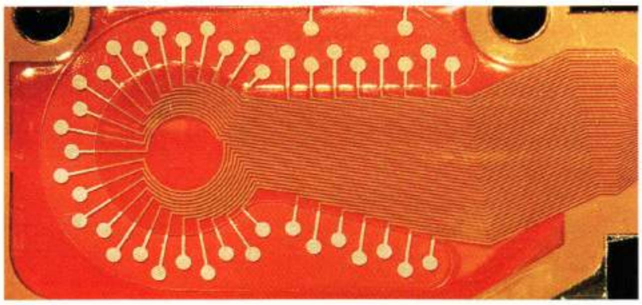


RISC computer architecture, invented by IBM researchers in the 1970s and introduced in 1986 in the IBM RT PC computer, enables a small computer to perform some applications at the speed of a large computer. RISC (Reduced Instruction Set Computer) technology emphasizes simplicity. The instruction set etched into logic circuits is reduced to basic, often-used commands that can be executed in a single machine cycle. By contrast, most other currently available computers use many multipurpose instructions that take several machine cycles to execute.

The Personal Computer



Personal computers with the processing power of medium-scale computers of the 1960s are winning wide acceptance in business and science, as well as in the home and schools. The low-cost systems of many producers are incorporating technologies developed over the industry's decades of innovation. The effect on most areas of computing is profound. In addition to delivering millions of machines each year for personal and commercial applications, the industry is developing networks of personal computers that promise further large gains in problem-solving and productivity. Such "intelligent" workstations can be operated as stand-alone computers, and users will also be able to communicate with many other linked workstations, as well as having access to large processors and data bases throughout the networks.



This 2-inch-long electronic printhead is a key element in the IBM-developed "resistive-ribbon" printing technology that "melts" characters onto the page. Printing is practically noiseless when compared with impact printing, which uses hammers or other electromechanical means. The technology is used in the IBM Quietwriter printers and typewriters. It can produce "letter-quality" printing at speeds up to 60 characters per second.

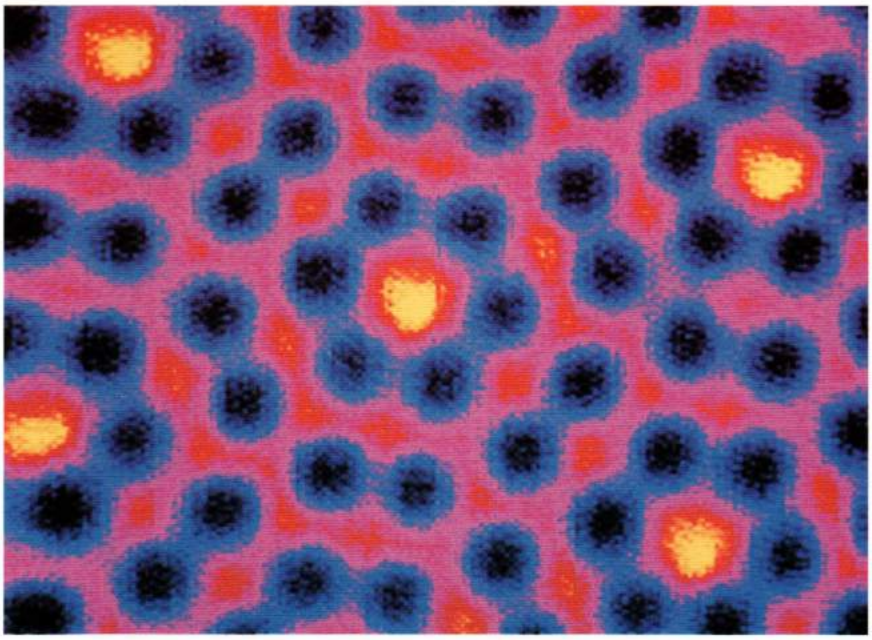
Research

Miniaturization, Plus

1980s

Foremost in the computer industry's research is a drive for thinner circuit lines, denser packaging, tinier read/write devices and other forms of miniaturization—the most significant technical force for raising speed and capacity and lowering costs. Researchers now work with circuit layers so thin they approach the atomic level.

Under test are experimental designs in parallel processing—systems that link hundreds of microprocessors, each more powerful than large-scale computers of the 1960s. Speech recognition is being brought closer to everyday practicality. Huge-capacity optical storage is under investigation.

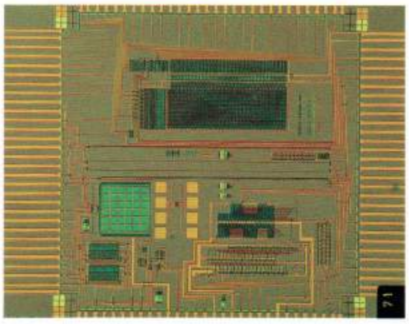


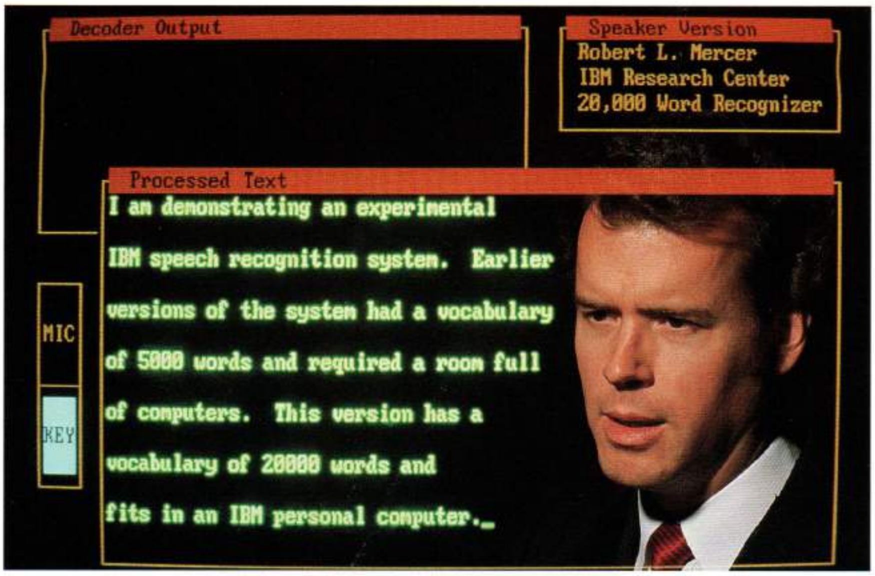
The world's first images of individual surface atoms and the bonds that hold them in place have been produced by a research technique developed by IBM—scanning tunneling microscopy. The picture above shows silicon surface atoms enlarged 20 million times, color-enhanced by computer. The scanning tunneling microscope (STM) was invented by IBM physicists Gerd K. Binnig and Heinrich Rohrer in 1981, work for which they were awarded a Nobel Prize in Physics in 1986. The invention permits scientists to obtain previously unseen images of silicon, nickel, oxygen, carbon and other atoms. Currently, STMs are being used or built by more than 50 research groups at universities and industrial laboratories throughout the world in a broad range of physical, chemical, biological and technical studies.

This is a small-scale version of the Scanning Tunneling Microscope (STM), invented by IBM researchers to produce images of individual atoms and the forces bonding them for the first time (photo at left). The smaller device allows wider use in scientific investigations. In scanning tunneling microscopy, a voltage is applied between a surface and a probe so sharp that its tip is a single atom. As the probe is moved to within a few atomic diameters of a surface, a "tunneling" current flows between the surface and the probe. The tip is then moved back and forth over the surface at a constant distance, accomplished by keeping the current constant. The continuous adjustment of the probe's vertical position produces a "contour map" of the surface, which is enhanced by computer processing.

Right: IBM scientists have produced the first experimental computer chips with half-micron line widths, thus shrinking circuits into an area 1/16th the size typical in computer manufacturing. A micron is a millionth of a meter.

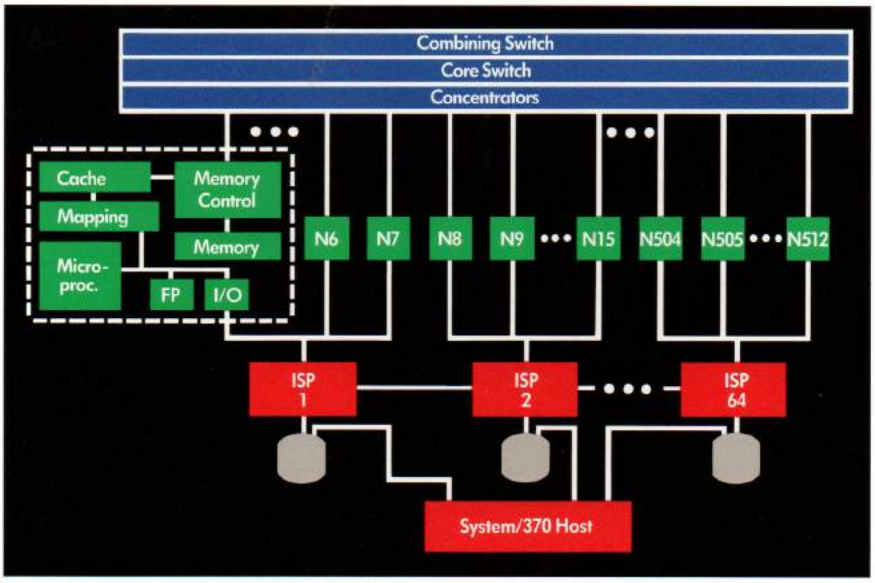
Left: Magnified 3,000 times is a computer memory circuit pattern created with a new "photoresist" material synthesized by IBM researchers. Such microscopic patterns are created by projecting light through a mask onto silicon coated with the photoresist, which is sensitive to extremely short wavelengths of light. The process can potentially produce chips storing many millions of bits of information.





Left: An experimental speech recognition system—the most advanced yet reported—can correctly transcribe sentences from a 20,000-word vocabulary with more than 95% accuracy. A new digital signal processor, integrated into an IBM PC AT computer in 1986, performs 30 million operations per second in speeding transcription of the spoken word.

IBM researchers are experimenting with new techniques for optical storage of hundreds of millions of characters of computer information per square inch in a medium that can be read, erased and rewritten. One approach coats disks with a thin film of magneto-optic material. Another uses thousands of laser light colors, or frequencies, to "bleach" groups of molecules to represent binary ones and zeroes.



IBM researchers are designing an experimental, highly "parallel" computer for use in advanced computer science studies. Initially designed with 64 processor "nodes," the RP3 system will be extendible to 512, linked in parallel and connected to as many as 2 billion characters of main memory. The 512-node version is planned to operate at a sustained speed of 1 billion instructions a second. Associated with a 32-bit microprocessor in each node are up to 4 million characters of memory; an intermediate, "cache," memory and memory-mapping circuits, plus floating-point arithmetic and input-output circuits. An IBM System/370 computer will collect data and manage programs, communicating through 64 input-output support processors.

The operating speeds of computer circuit chips could increase significantly with "ballistic electron-transfer" techniques being studied by IBM researchers. The scientists have found that when "excited" electrons are injected through very thin, super-cooled layers of aluminum gallium arsenide, more than 40% make it through without measurable energy loss. With current technologies, electrons typically lose speed and direction as they encounter vibration and collisions with impurities in the semiconductor circuit medium.

A major development in the field of mathematics, fractal geometry, was conceived and developed by an IBM research mathematician and first published in 1975. Fractal geometry deals with irregular, fractured shapes—or "fractals." Fractal geometry embodies the tendency of natural forms to repeat themselves, as with the resemblance between a coastline and the shore of one of its inlets. The new geometry is being applied in fields ranging from aerodynamics and art to astronomy, linguistics and metallurgy.

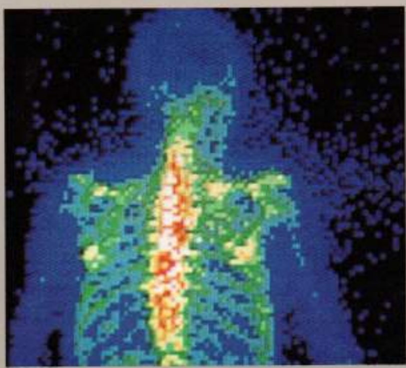
Benefits from Technology

Year by year, the demand for new computer technology continues to expand. Why? The answer lies in the world's need for greater productivity. Businesses wish to provide more complete and responsive services. Manufacturers seek lower costs, while improving quality and maintaining schedules. Hospitals strive for more efficient health care. Governments at every level search for ways to serve many needs, while staying within limited budgets. Farmers seek healthier crops and livestock, while making the best use of feeds and equipment. Individuals look for ways to manage personal finances better, improve family education and make home equipment more efficient.

For these and many other requirements, computers can be an important part of the answer. They are broadly adaptable to each user's needs. They are available in low-cost models easy to set up and use . . . office systems with many features that simplify and speed paperwork . . . powerful computers for complex tasks . . . communication systems that let widely separated units of an organization function smoothly as parts of the whole. And the cost keeps going down.

As a result, computers are multiplying everywhere—in the warehouse, in the emergency room, at the sales counter, in the classroom, at the secretary's desk, in the fire station, in the home, outside the bank and in the town hall. And no limit is in sight to the ways computers can be used to help more people—wherever they live around the world.

More productive farm management



Aid in diagnosing illness

Studies of earth and sea resources

How New Technology Has Lowered the Cost of Information Processing

This chart shows the time and cost for large IBM computers to complete a fixed amount of data processing. The figures in each column are based on an identical mix of 1,700 typical data processing operations, involving millions of computer instructions. Included is a cross section of payroll, discount computation, file maintenance, table lookup and report preparation. Figures show costs of the period, not adjusted for inflation.

	1955	1960	1965	1975	1987
Cost	$14.54	$2.48	47¢	20¢	4¢
Processing Time	375 sec.	47 sec.	29 sec.	4 sec.	0.4 sec.
Technology	*Vacuum tubes Magnetic cores Magnetic tape Magnetic drum*	*Transistors Channels Faster cores Faster tape*	*Solid Logic Technology Large, fast disk files New channels Larger, faster core memory Faster tape*	*Monolithic memory Monolithic logic Virtual Storage Virtual Machine Larger, faster disk files New channels Advanced tape*	*High-capacity memory chips Very dense logic packaging Extended Architecture Thin film head disk technology Magnetic cartridge tape 1-million-bit chip RISC technology*
Programming	*Stored program*	*Overlapped input/output Batch processing*	*Operating system Faster batch processing*	*Advanced operating systems Virtual Storage Virtual Machine Multiprogramming Batch, plus on-line processing*	*Full-function, advanced operating systems Multiprocessing Advanced networking products Extended Architecture Comprehensive data base facilities Interactive, user-oriented functions*

IBM